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Experimental determination of temperature, electronic density and air pumping in an oxygen plasma cutting arc

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Abstract: This paper deals with the experimental characterization of an oxygen plasma cutting torch. Optical spectroscopic methods were performed to determine temperature, electronic density and nitrogen rate values. This study concerned the region situated under the shock wave located in the immediate vicinity of the nozzle exit.

1. Introduction

Several investigations about oxygen plasma cutting torch were realized previously in our laboratory [1-2]. They deal with an arc model, but few experiments were made to validate this numerical treatment. The jet is supersonic and turbulent, with the presence of a shock wave in the immediate vicinity of the nozzle exit. Pressure relaxes to the atmospheric pressure on a short distance, in the order of few millimeters. The study presented in this paper concerns the region under this shock wave, where the LTE assumption is valid. Results about temperature, electronic density, and air pumping in the plasma jet will be reported.

2. Device presentation

2.1. Torch configuration

The plasma cutting torch is an OCP 150 system marketed by "Air-Liquide" company. The simplified torch design is shown in figure 1. The injected gas is first argon for arc striking, then oxygen when the arc is transferred to the metal workpiece. In our configuration, the plate to be cut is a rotating disk (the anode) situated further down at 15 mm, allowing spectroscopic measurements. In the real cutting configuration, this distance would be 3 mm from the nozzle exit.

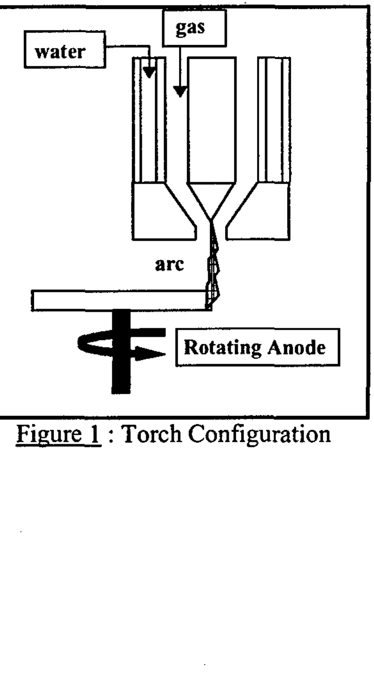

Figure 1 : Torch Configuration

2.2. Experimental setup

In the acquisition device, an optical system, which magnification equals 2.0, allows horizontal (x) and vertical (z) scans. The lines are selected by a Jobin-Yvon monochromator. A Hamamatsu CCD camera transforms the integrated intensities in electric signals received by a computer.

2.3. Experimental conditions

Spectroscopic measurements were performed under the shock wave, for different axial positions z= 3, 6, 9, 10 and 12 mm along the jet. The arc current is fixed at 60 A and the voltage is 200 V, for an oxygen flow rate of 6.5 $l.min^{-1}$.

3. Diagnostic methods

3.2. Electronic density

The electronic density was deduced from the Stark broadening of the OI oxygen line at 645,6 nm and the H Balmer α line at 656,3 nm, according to Griem theory [3-4]. Apparatus function is neglected (~0.04 nm). It is noteworthy that the pumping of nitrogen doesn't change significantly the electronic density, since the nitrogen ionization energy value is very near the oxygen one.
Method related to the continuum emission was performed to determinate the electronic density. The contributions of the radiative recombination and Bremsstrahlung (e-ions and e-atoms) were calculated [5].

3.1. Temperature determination

The Folwer-Milne method [6] was applied for the temperature determination. This technique requires an axial temperature of the plasma greater than the temperature corresponding to the maximum emission (for the OI 777.3 nm and the OI 884.6 nm, the maximum emission temperature is 15500 K at atmospheric pressure). Nevertheless, this method depends strongly both on the pressure and the plasma composition. Temperature profiles can also be obtained by combining the plasma composition, under LTE assumption, with the electronic density values deduced from Stark Broadening measurements.

3.3. Nitrogen pumping in the plasma jet

In our experimental conditions, the molecular species N_2 and N_2^+ are negligible in comparison to NI atoms. Moreover, NII ions must be taken into account. The atomic NI nitrogen density is calculated from the Boltzmann's law and the emissivity of the NI 744,3 nm line. Since the air proportion entering the plasma doesn't influence the ratio NI/NII [5], the atomic ion NII density can be easily deduced. The nitrogen rate is finally obtained from the Dalton's law [5].

4. Results

4.1. Temperature profiles

Two points can be mentioned from the figure 2. The first concerns the temperature decrease as long one go far from the nozzle exit. The second is about the crossing point of the curves due to the plasma expanding for high z values.

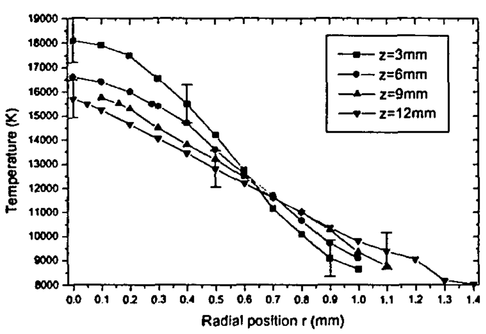

Figure 2 : Temperature profiles

4.2. Electronic density

The continuum method gives electronic density values higher than the values for an oxygen plasma at atmospheric pressure (figure 3). This discrepancy may be explained by the too low continuum intensity.
On the other hand, one can note a good agreement between the electronic density given by Stark Broadening of Hα and OI 645.5 nm lines and the LTE values. This result indicates the LTE assumption is valid for z=10 mm, excepted on the plasma edges.

4.3 Nitrogen rate in the plasma

Whatever the considered axial z position, the nitrogen rate on the axis stays lower than 10% (figure 4) in spite of turbulence. The nitrogen rate grows approximately to the air values for external part of the plasma.

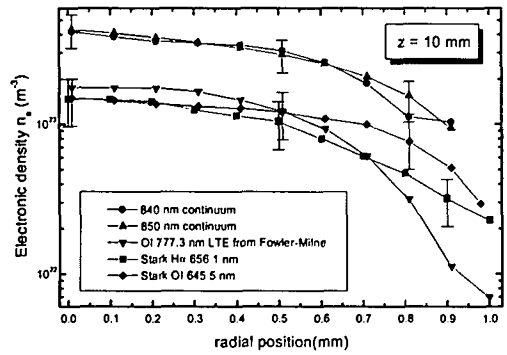

Figure 3 : electronic density profiles

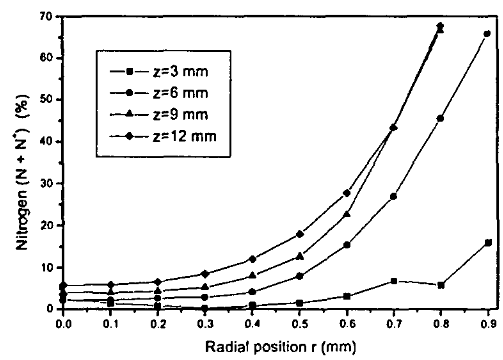

Figure 4 : Nitrogen rate

5. Conclusion and perspective

Other spectroscopic measurements have been done in the shock wave and at the nozzle exit. These results will be presented soon. Furthermore, in real cutting configuration, we intend to study the energy transfer from the arc to the plate, and the influence of different parameters such as speed on the shape of the cut kerf. Measurements based on the use of thermocouples, a CCD camera and a pyrometer are planned.

6. References

[1] P. Freton, University Paul Sabatier (Toulouse 3), Thesis, (2002).
[2] P. Freton, J.J. Gonzalez, A. Gleizes, F. Camy-Peyret and G. Caillibotte, *J. Phys. D: Applied Phys.* **35** (2002) 115.
[3] Griem H.R., Plasma Spectroscopy, Mc Graw-Hill, New York, (1964).
[4] Griem H.R., Spectral lines broadening by plasma, Academic Press, New York, London, (1974).
[5] Y. Cressault, University Paul Sabatier (Toulouse 3) Thesis, (2001).
[6] Vacquié S, *L'arc électrique*, Editions Eyrolles et CNRS éditions, (2000).